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Factors Affecting Line Tracing in Tactile Graphs

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Abstract

Twenty-four braille readers in grades 4-12 performed a line tracking task on tactile line graphs which differed in the type of raised line used to represent the data curve (continuous-interrupted, narrow-wide) and the nature of the display background (grid, no grid). A grid was found to impair the trackability of every line tested, despite high levels of discriminability between the test lines and the grid line. In general, tracking proficiency was independent of line type and grade level. Implications for the design of tactile line graphs for the blind are discussed.

Factors Affecting Line Tracing in Tactile Graphs

In recent years an awareness of the need for a variety of tactile nonverbal graphic displays in the education of blind children has grown considerably, possibly as a result of the increasing percentage of such material appearing in printed form (Kirchner, 1979). Production of such displays has thus accelerated accordingly, revealing a myriad array of problems associated with the translation of visual graphics into tactile form. One of the more basic problems that had to be attended to initially involved tactual symbology. As is the case for visual graphics, tactile graphics require three classes of symbols for conveying the pertinent information. Areal symbols are needed to differentiate areas, point symbols to identify specific locations, and linear symbols to identify boundaries or to connect points. Usable candidates from each symbol class were not, however, readily apparent (many visually different symbols cannot be discriminated tactually), and so the search for legible sets of the three types of symbology began in earnest. A series of studies conducted in 1963 by Nolan and Morris, for example, identified a highly discriminable set for each symbol class, using vacuum-formed plastic as a medium. Other studies (Gill & James, 1973; James & Gill, 1975; Nolan & Morris, 1971) generated alternative symbol sets, in both plastic and paper.

In the present experiment, linear symbology was the primary focus of study. In all of the studies mentioned above, psychophysical data were used to identify a set of linear symbols that were mutually discriminable. Although such a strategy is valuable in the initial selection of a working set of lines from a pool of possibilities, it offers no information or guidelines for

choosing one line over another within a set. If a particular tactile display requires the use of only one linear symbol, or, for that matter, any number fewer than the total set size, little information is available upon which to base one's decision of line (or lines) choice. A knowledge of the relative ease with which each line is tracked would thus contribute greatly to this selection process.

Of course, lines are not always used in graphic displays in isolation from other types of symbology. In some instances, for example, they are embedded in a background of areal patterns. While such a situation has been found to impair the trackability of one linear symbol (Berla' & Murr, 1975a), no information is available on the relative resistance of different kinds of lines to such deterioration.

Line graphs represent an important instance of the above type of display, with lines representing data curves being displayed against a background grid. The task of tracking a data curve embedded in a grid might be analogous to the situation involving a line embedded in an areal pattern. If so, impaired trackability of the data curve would be expected. Despite the widespread use of line graphs in tactile publications, however, no effort has been made to obtain such basic information. Other display variables not yet explored include the type of line that is most easily tracked through a grid, the type of line used in composing a grid, the grain of a grid, and the separation between grid and data curve.

The purpose of this study was to assess the effects of line type and the nature of the background on line tracking efficiency. Line type was studied in terms of two of the most important parameters which distinguish one linear

symbol from another: continuity and width (Nolan & Morris, 1971). These were chosen in preference to a third important parameter, single-double, since Bentzen and Peck (1979) and Easton and Bentzen (1980) have already established that single lines result in faster exploration times and better memory representations than double lines.

The lines used in testing were displayed against either a grid background or a smooth background (that is, the absence of any competing tactual elements). The grid was composed of narrow solid lines since it is this type of grid which is most frequently encountered in tactile publications. The grid was lower in elevation than the lines embedded in it. Finally, the graphic displays were embossed in paper, a medium, which, despite its widespread use, has received a paucity of attention from researchers in the area of tactile displays.

This experiment was viewed primarily as a research effort to provide basic information on tactile graphs and tactile linear symbology. First of all, the overall magnitude of difficulty in tracking a line through a background grid was determined. This was computed as a percentage increase in tracking time from the level achieved when no grid was present. Similar information was obtained for each line type. Secondly, the types of line (interrupted vs. continuous, wide vs. narrow) that are most efficiently tracked when no areal patterns are present were identified.

Besides indicating the general effect of a grid on tracking efficiency, such information may provide a basis for one's decision of line choice, both in situations involving grids and those not involving grids.

Method

Subjects

The subjects were 24 legally blind students enrolled in a residential school for the blind. Twenty-two of these students were totally blind and two had light perception. All were academic types with no debilitating physical handicaps other than visual impairment, and braille was their primary mode of reading. Eight students were randomly selected from each of the following grade groupings: 4-6, 7-9, 10-12. Table 1 shows the grade placement, chronological age (CA), and sex distribution of each of these groupings.

Insert Table 1 about here

Materials

Eight line graphs were drawn, each confined within a 10 X 10 inch (25.4 X 25.4 cm) display frame. In order to be reasonably assured that all eight distinct line patterns were equivalent to one another, several criteria were adhered to in their construction. All eight patterns thus shared the following characteristics:

1. four upward turns at junction points (a junction point being the place at which the direction of a line changes)
2. four downward turns at junction points
3. an approximately equal distance in line-tracking away from the body and towards the body

4. two horizontal lines [1 inch (25.0 mm) and 2 inch (50.0 mm)]
5. a total line length of 19.7 inch (50.0 cm)

In reality, only four of the patterns were constructed in this manner. The remaining four were generated by simply inverting the original set of four patterns. The final result was a set of eight line patterns which differed in spatial configuration but not in complexity. Table 2 indicates the type of line and the type of background used in composing each of these eight displays. The eight different line configurations described ~~above~~ were randomly assigned to the eight unique combinations of line type and background.

Insert Table 2 about here

Insert Figure 1 about here

Each of these displays was embossed in a zinc plate by the stereograph department at the American Printing House for the Blind. These metal masters were then used to impress the graphic patterns in heavy braille paper, .006 inch (.15 mm) in thickness. Symbol elevation was measured by a paper micrometer (Teclock Dial Gauge), with adjustment made for the thickness of the paper medium. Determinations of line width were made by measuring the distance between the points where the paper began to rise to form the sides of the linear symbol.

The elevation of the eight raised lines was approximately .020 inch (5.1 mm). The width of the wide lines was approximately .13 inch (3.3 mm), while the width of the narrow lines was approximately .08 inch (2.1 mm), a difference of line width which Berla' and Murr (1975b) found to be discriminable by more than 90% of the students they tested. In order to control for the possibly confounding effects of rhythm, the interval between the centers of the dots composing both the narrow and wide interrupted lines was held constant at .16 inch (4.0 mm).

The background grid used in four of the displays had a .75 inch (1.9 cm) grain. The width of the line used to form the grids was .07 inch (1.7 mm). Elevation of the grid line was .010 inch (.26 mm). Separation between the grid and the graph line embedded in it for each of these four displays was approximately .12 inch (3.0 mm).

In addition to the eight test displays described above, three others were constructed for purposes of familiarization and training. The first of these was a line graph displayed against a smooth background with the raised line consisting of an alternating dot-dash pattern. The width and elevation characteristics of this line were similar to those of the narrow interrupted and narrow continuous lines described previously. The second display was a 10 X 10 inch grid, with no lines embedded in it. The third consisted of an alternating dot-dash line embedded in a grid background. The dimensions of this line were comparable to those of the wide interrupted and wide continuous lines used in testing.

Finally, five different types of raised lines were produced in lengths of 8.0 inch (20.5 cm) for discrimination testing, displayed against a smooth background with dimensions of 1.6 X 8.0 inch (4.0 X 20.5 cm). This set included the following lines: wide interrupted, narrow interrupted, wide continuous, narrow continuous, and grid line.

Procedure and Design

At the beginning of testing each student was informed as to the purpose of the study and the nature of the tasks to be performed. Each student was seen individually in two separate sessions. In the first session, half of the students from each grade grouping were tested on the four displays with background grids, while the other half were presented with the four displays without grids. In the second session, each subject was presented with the set of displays not yet encountered. Assignment of subjects to these two orders of presentation was randomly determined.

Because Berla', Butterfield, and Murr (1976) have found that line tracking is difficult for many blind students in grades 4-12, all subjects were given a short training period on line tracking in order to attenuate between-subjects variability. The technique of using the index finger of both hands, one for following the line, the other for maintaining a reference point, was the tracking skill taught to all subjects. The training graph used for this purpose consisted of a raised line against a smooth background. This display, as well as those to follow, was mounted on a clipboard with nonslip rubber backing. When the experimenter was assured that the subject was employing this skill properly, the training graph was inverted and the

subject was required to trace the line from beginning to end without assistance. If tracking time exceeded 2 minutes, additional training was given, the graph was inverted, and the subject tried again. Following a successful tracing, a raised-line grid was presented for tactual inspection and its characteristics were described. A second training graph, consisting of a raised line embedded in a grid background, was then introduced. Each subject attempted to trace the line through the grid. If tracing time exceeded 2 minutes, the display was inverted for a second attempt. Speed and accuracy were emphasized.

The four trials which immediately followed the training period involved tracking the four different types of linear symbols. On each of these trials, the subject was instructed to trace the line on the test display from the beginning to end as quickly as possible without departing from the line. Each subject performed these tasks on new, unused paper copies of the displays. If the subject's lead finger and reference finger lost contact with the line, or if s/he skipped a section(s) of line, the experimenter took the subject's finger and returned it to the point of departure. The departure point was marked on the display itself and recorded as an error on the data sheet. Duration of tracking, as measured by a stopwatch, was also recorded.

In order to control for the confounding effects of learning and fatigue on performance, each subject received a different order of presentation of the four line types. All 24 possible orderings were represented in both the grid and no grid conditions. A given ordering of linear symbols was randomly assigned to each subject.

Session II (generally given within 24 hours of Session I) began by having the subject trace the lines on the two training graphs using the two-finger method. Following these refamiliarization tasks, four test trials were conducted, using the same procedure as in Session I. The only difference was the type of background against which the lines were displayed (grid or no grid, depending on which condition the subject received in Session I).

At the completion of the four tracking tasks, line discrimination was begun. The five different types of lines were mounted two at a time on the clipboard, one above the other, with a separation distance of 5 cm. Scanning was done horizontally, and no time limits were imposed. The order of the 15 possible line-pair combinations (each line typed was also paired with itself) was randomly determined for each subject. Moreover, the spatial positions (top-bottom) of the line types within each pair-comparison trial were also assigned randomly. Subjects were simply told to examine tactually each of the 15 pairs of lines and report whether they were alike or different. Responses were recorded as correct or incorrect on a data sheet.

Finally, all subjects were asked to rank the lines in terms of their ease of tracking. All five lines were examined and a first choice made. This line received a rank of 1. A second line was then chosen. This procedure continued until one line, the least preferred (rank = 5), remained. This concluded Session II and the experiment for that subject.

Results

Tracking Time

A 2 X 2 X 2 X 3 analysis of variance for mixed designs was applied to the tracking data, which consisted of the times required by each subject to trace the raised lines in eight test displays. Type of background, width of line, and continuity of line constituted the within subjects' factors, and grade level constituted the between subjects' factor. Because of the presence of a few extreme scores, the median and semiinterquartile range are used for descriptive purposes (Note: Twice the semiinterquartile range is the distance which contains the central 50% of the scores).

The most powerful factor contributing to the variability within subjects was the type of background through which a line was tracked. The median tracking time for the no grid condition was 8.5 seconds, compared to a median time of 21.5 seconds for the grid condition. This difference, representing a 153% increase in tracking time from the no grid to grid condition, was highly significant, F (1,21) = 41.41, $p < .001$. The presence of a background grid is thus extremely disruptive to the task of tactually tracking a line embedded in it. Furthermore, a grid was found to increase response variability, as is evident from the semiinterquantile ranges of tracking times reported in Table 3. Moreover, extreme variations in tracking duration occurred only in the grid condition.

Insert Table 3 about here

Several significant interaction effects were found. However, only the higher order interaction between line width, line continuity, and background [F (1,21) = 19.28, $p < .01$] need be elaborated upon, since all the pertinent information is contained within it. Generally, it can be said that the effect of line type on tracking performance was dependent upon the nature of the display background. This dependency can be seen in the median tracking times for the eight unique combinations of these factors (see Table 3).

A post hoc analysis of these data using a Newman-Keuls procedure revealed the following pattern of results:

1. Each of the four lines embedded in a grid differed from each of the four lines not embedded in a grid ($p < .01$).
2. The narrow continuous line embedded in a grid differed from all other lines embedded in a grid ($p < .01$).
3. Except for the narrow continuous line, all lines embedded in a grid did not differ from each other ($p > .05$).
4. Lines not embedded in a grid did not differ from each other ($p > .05$).

Once again it is evident that the grid background had a deleterious effect on tracking performance, an effect which was not offset by any combination of line width and continuity. In the case of the narrow continuous line, which was distinguishable from the grid lines almost exclusively on the basis of elevation, tracking performance was particularly affected by the presence of the grid. Tracking time for this line increased by 354% from the no grid to the grid condition. In comparison, the wide interrupted line showed an increase of 100%, the narrow interrupted line an increase of 104%, and the wide continuous line an increase of 117%.

Finally, the time scores were analyzed with respect to grade level. These data are reported in Table 4. The apparent difference in tracking times between the grade groupings fell short of significance, $\underline{F}\ (2,21) = 2.22$, $\underline{p} > .05$, indicating that grade level is not a significant factor in determining the speed with which a student can track a raised line. Moreover, the lack of differences between grade levels held even when a raised line was tracked through a background grid. Grades 4-6 took 165% more time to track lines embedded in a grid than to track those same lines displayed against a smooth background. Grades 7-9 took 134% more time, and grades 10-12 showed an increase of 83%. This apparent interaction effect of grade level with background, as well as the interaction effects of grade level with all other experimental factors, failed to attain statistical significance.

Insert Table 4 about here

Errors

An error was recorded whenever a subject's fingertips strayed from the line or when a section (or sections) of the line was skipped. Such line departure errors were committed by 7 of the 24 subjects. Only two of these seven committed errors on more than one display. A nonparametric Chi-Square Test for independent samples revealed no differences in error rate attributable to grade grouping, $\underline{X^2}$ (2 df) = 1.63, $\underline{p} > .05$. Although the majority of subjects who committed errors did so in the grid condition, a McNemar Test for correlated samples failed to detect a significant difference between the grid and no grid conditions, $\underline{X^2}$ (1 df) = 2.67, $\underline{p} > .05$. Further consideration

of the grid condition itself, however, indicated that the number of subjects who committed errors was dependent on the type of line that was tracked through the background grid. A Cochran Q Test revealed significant differences in error frequency due to line type, Q (3 df) = 13.1, $p < .01$. Two-thirds of the line departures in the grid condition occured when tracking involved the narrow continuous line. Typically, these departures occurred at junction points, where the direction of a line changes.

Line rankings

In order to determine subjective preferences with respect to line type, all subjects were asked to rank the set of five lines (the four test lines plus the grid line) in terms of their ease of tracking. A rank of 1 was applied to the most preferred line, a rank of 5 to the least preferred. The mean rank of each line is shown in Table 5.

Insert Table 5 about here

The difference between these line rankings was found to be highly significant by a Friedman Two-Way ANOVA, X^2 (4 df) = 58.76, $p < .001$. Multiple comparison tests based on the Friedman rank sums (Hollander & Wolfe, 1973) revealed the following pattern of significant differences ($p < .05$):

$$\underline{\mathrm{NI}\qquad\underline{\mathrm{WI}}}\underline{\qquad\mathrm{WC}\qquad\mathrm{NC}}\qquad\mathrm{GL}$$

The ranks of linear symbols underlined by a common line do not differ from each other; those not underlined by a common line do differ significantly. Thus, the narrow interrupted line was preferred over all other line types,

except the wide interrupted line. No differences in preference were found between the wide interrupted line, the wide continuous line, and the narrow continuous line. Finally, the narrow continuous grid line of low elevation was least preferred, receiving a mean ranking which set it apart from all other line types.

Line Discrimination

Pair comparison data obtained from each of the 24 subjects indicated that the five lines described above are easily discriminated from one another tactually. Only four subjects committed errors in discrimination, and none of these committed more than one error. All four errors occurred when a line was being compared with itself (GL = 2, NC = 1, WC = 1). It can therefore be said that all five of the linear symbols produce distinct tactual impressions, thus permitting the use of all five in the same display if need be.

Discussion

As expected, a grid background was found to have adverse effects on line tracking performance. On the average it took students 153% longer to track a line through a grid background than through a smooth background. This occurred despite the fact that the lines composing the grid were only half as high in elevation as the lines embedded in them. Moreover, the separation between the grid lines and the graph lines was .12 inch (3.0 mm), a value greater than the intersymbol distance of .09 inch (2.3 mm) suggested by Nolan & Morris (1971) for efficient readability. This decrement in tracking efficiency occasioned by the presence of a grid is similar to the effect

found by Berla' and Murr (1975a) in a study involving areal patterns. It took their subjects 41% longer to follow a tactile track on a plastic map containing texture than on one containing no texture. It seems clear that a background grid can be considered as an areal pattern which adds "noise" to a tactile display. It adds tactual stimulation which is attention demanding and difficult to filter out, even when there is no question of it being discriminable from the line embedded in it.

Generally, it cannot be said that line width, line continuity, or any combination of these two factors has an effect on the efficiency of line tracking, at least within the constraints of this experiment. This is in contrast to the opinion of Angwin (1968) and Wiedel & Groves (1969) that narrow dotted lines are easier to follow. No such effect emerged.

All four of the raised lines tested in this study were harder to follow in the grid condition than in the no grid condition. This fact again emphasizes the potency of the distracting effect of a grid background, since three of these lines differed from the grid lines in two or more tactile characteristics (width, continuity, elevation). The line differing in three tactile attributes (wide interrupted) was tracked no faster than the lines differing in two attributes (narrow interrupted, wide continuous). However, when the difference between the grid line and the tracked line was reduced to one attribute (in this case, elevation), performance deteriorated. Not only did tracking time increase, but line departures also increased. Although this effect occurred for the narrow continuous line in the present study (using a

narrow continuous grid line), much the same effect would be expected for a narrow interrupted line embedded in a grid of narrow interrupted lines, differing only in elevation. An elevation difference of two to one was not sufficient in itself to insure efficient tracking performance.

Statistically, no effect of grade level on line tracking performance could be discerned. This finding is not unusual in the area of tactual perception. Nolan & Morris (1971), for example, found no differences between grade levels in the ability to discriminate areal, point, and linear symbols, while, in a series of studies by Berla', grade differences failed to emerge in the accuracy and latency of locating shapes on a tactile pseudomap (Berla', Butterfield, & Murr, 1976), and in the time needed to follow a tactile track through textured and nontextured backgrounds (Berla' & Murr, 1975a). It would appear that many tactual abilities are fairly well developed by the time a student reaches the fourth grade. Alternatively, it may be that grade level effects are not typically found because tactual perceptual capabilities and, consequently, tactual performance, is inferior throughout all grade levels. In this regard, Berla', Butterfield, & Murr (1976) found that the inability to trace lines was a persistent problem that permeated all the grades he tested (4-12). In the present research study, there were indications that performance improved from the 4th to 12th grade, particularly in tracking a line through a grid, but no reliable differences were found. It should be noted, however, that the inclusion of a larger number of subjects from each of the three grade groupings would have resulted in a more powerful test of the effects of this variable.

Conclusions

Twenty-four braille-reading students from grades 4-12 traced four raised lines differing in continuity and/or width through both grid and no grid backgrounds. Because the presence of a grid was found to retard tracking speed significantly for every line tested, it is recommended that caution be exercised in the use of a grid in tactile line graph displays. When the shape of a data durve or the general relationship between two data curves is the primary information to be conveyed by a graph, a grid probably should not be used. For every graph placed in a braille textbook, a decision should be made as to whether or not the precise location of points on the data curve represents an important purpose of that particular graph. If it is, a line (or lines) should be chosen which differs from the grid lines in at least two tactile characteristics. Furthermore, the two-finger method of tracking a line should be taught to all students, as this skill helped reduce the problem of line departures in the grid condition. Many departures were averted because the subject's left index finger remained in contact with the graph line while the right index finger searched for the continuation of the line.

Research should be conducted to determine whether or not practice might attenuate the deleterious effect of a grid on tracking speed. It should also be determined whether a larger separation between a grid and the line(s) embedded in it could be employed to facilitate tracking speed without impairing the speed and accuracy of precisely locating the coordinates of a point on that line.

Based on the tracking efficiency data obtained in this study, there is no reason to select one linear symbol over another for use in a tactile display which does not contain a grid. However, because the narrow interrupted (dotted) line was clearly preferred by the braille-reading participants, it is recommended that this type of line be employed whenever it is feasible to do so. If more than one linear symbol is to be used in a graphic display, a narrow interrupted line should be employed to represent the line of primary interest.

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Table 1

Demographic Data

Grade groupings	4-7	7-9	10-12
Grade placement	M = 5.2	M = 7.4	M = 10.4
	SD = 1.0	SD = .5	SD = .5
CA	M = 11.4	M = 13.0	M = 16.5
	SD = .7	SD = .8	SD = .9
Male-female	5-3	3-5	4-4

Table 2

Composition of Graphic Displays

Graph	Line type[a]	Background
1	Narrow interrupted	Grid
2	Narrow interrupted	Smooth
3	Wide interrupted	Grid
4	Wide interrupted	Smooth
5	Narrow continuous	Grid
6	Narrow continuous	Smooth
7	Wide continuous	Grid
8	Wide continuous	Smooth

[a] See Figure 1

Table 3

Median Tracking Times (in seconds) for Line Type and Display Background (semiinterquartile ranges in parentheses)

	Background		
Line type	Grid	No grid	*Overall*
Narrow interrupted	16.5 (6.4)	8.1 (2.0)	11.0 (5.1)
Wide interrupted	21.0 (6.2)	10.5 (3.3)	14.5 (6.4)
Narrow continuous	29.5 (7.8)	6.5 (2.3)	16.0 (11.2)
Wide continuous	18.5 (5.2)	9.0 (3.8)	14.2 (4.9)
Overall	21.5 (7.1)	8.5 (4.6)	

Table 4

Median Tracking Times (in seconds) for Grade Groupings and Display Background (semiinterquartile ranges in parentheses)

	Background		
Grade grouping	Grid	No grid	*Overall*
4-6	26.0 (4.6)	9.8 (3.8)	19.5 (8.5)
7-9	18.5 (6.6)	7.9 (4.0)	14.0 (7.0)
10-12	14.8 (5.0)	8.1 (2.8)	11.5 (4.7)
Overall	21.5 (7.1)	8.5 (4.6)	

Table 5

Mean Rank of Five Linear Symbols

Narrow Interrupted (NI)	Wide Interrupted (WI)	Narrow Continuous (NC)	Wide Continuous (WC)	Grid Line (GL)
1.7	2.2	3.2	3.0	4.9

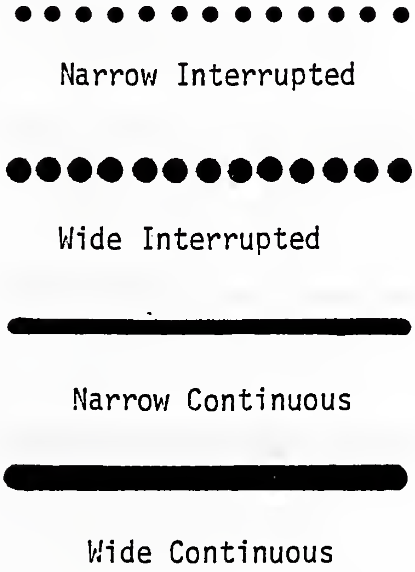


Figure 1. Four linear symbols (actual size) differing in width and/or continuity.

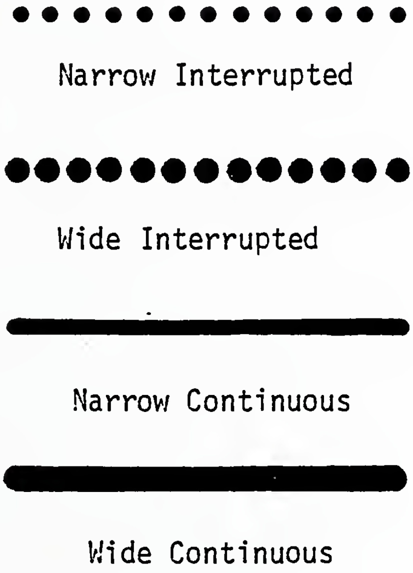
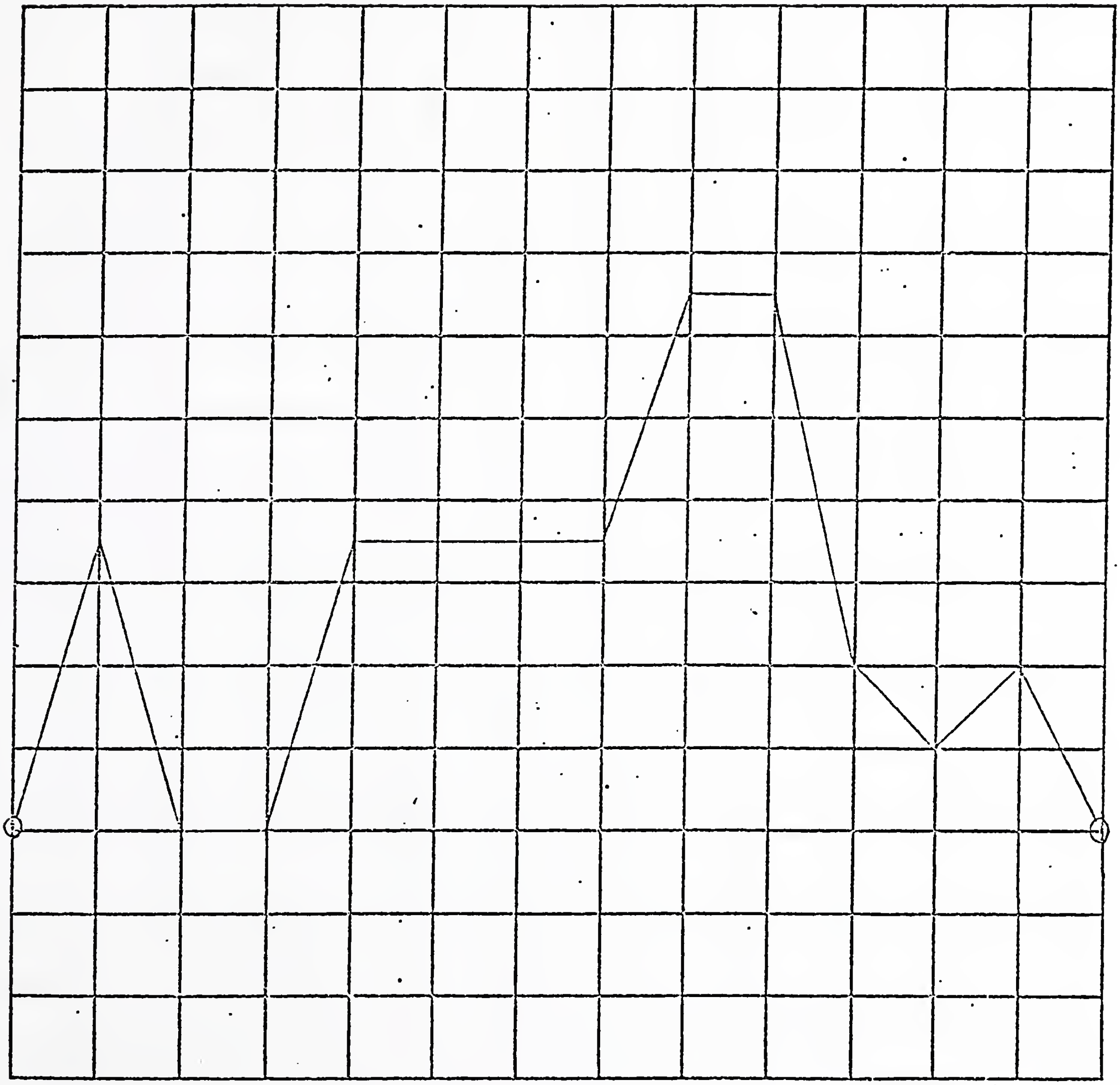


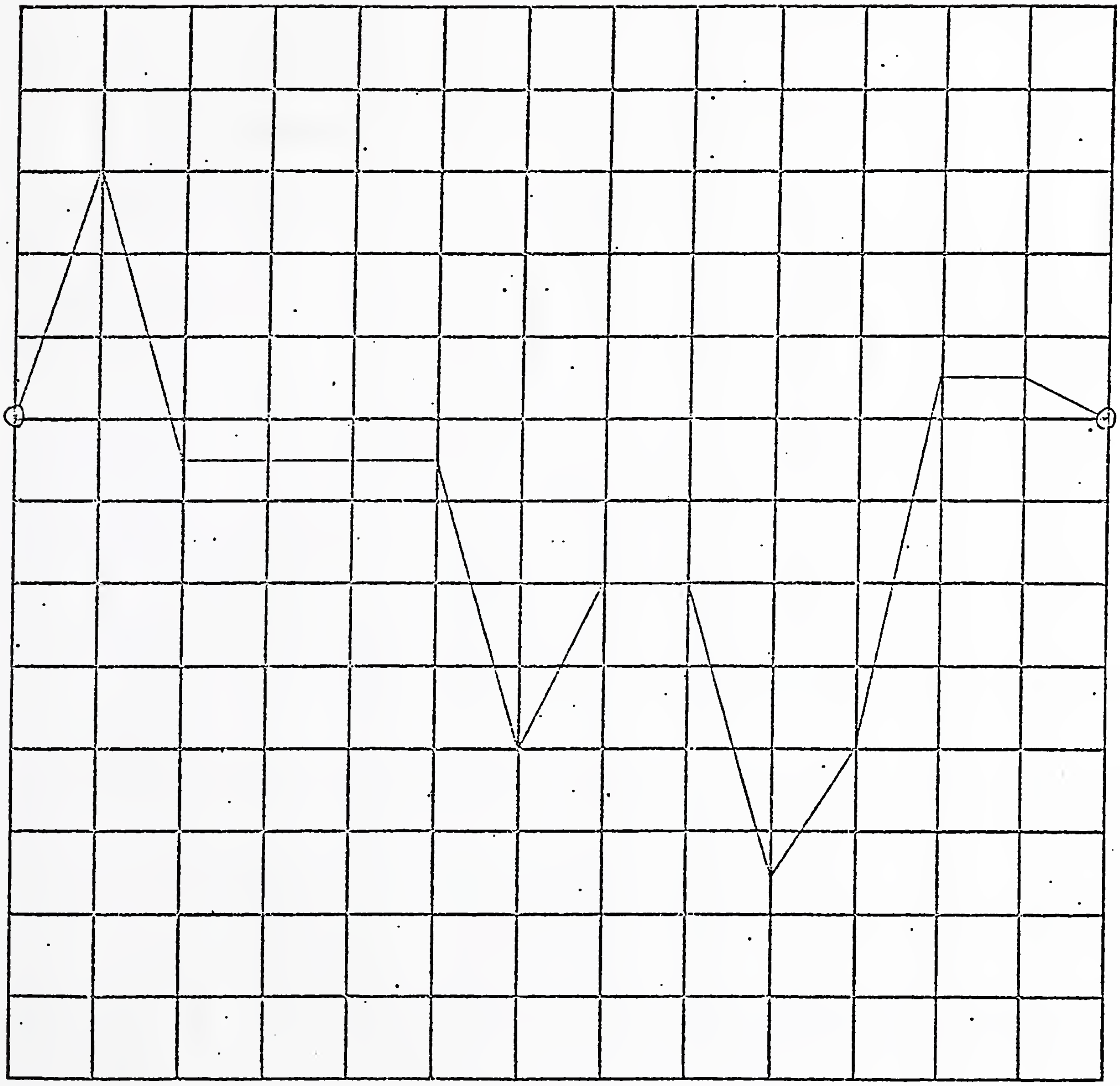
Figure 1. Four linear symbols (actual size) differing in width and/or continuity.

Appendix A

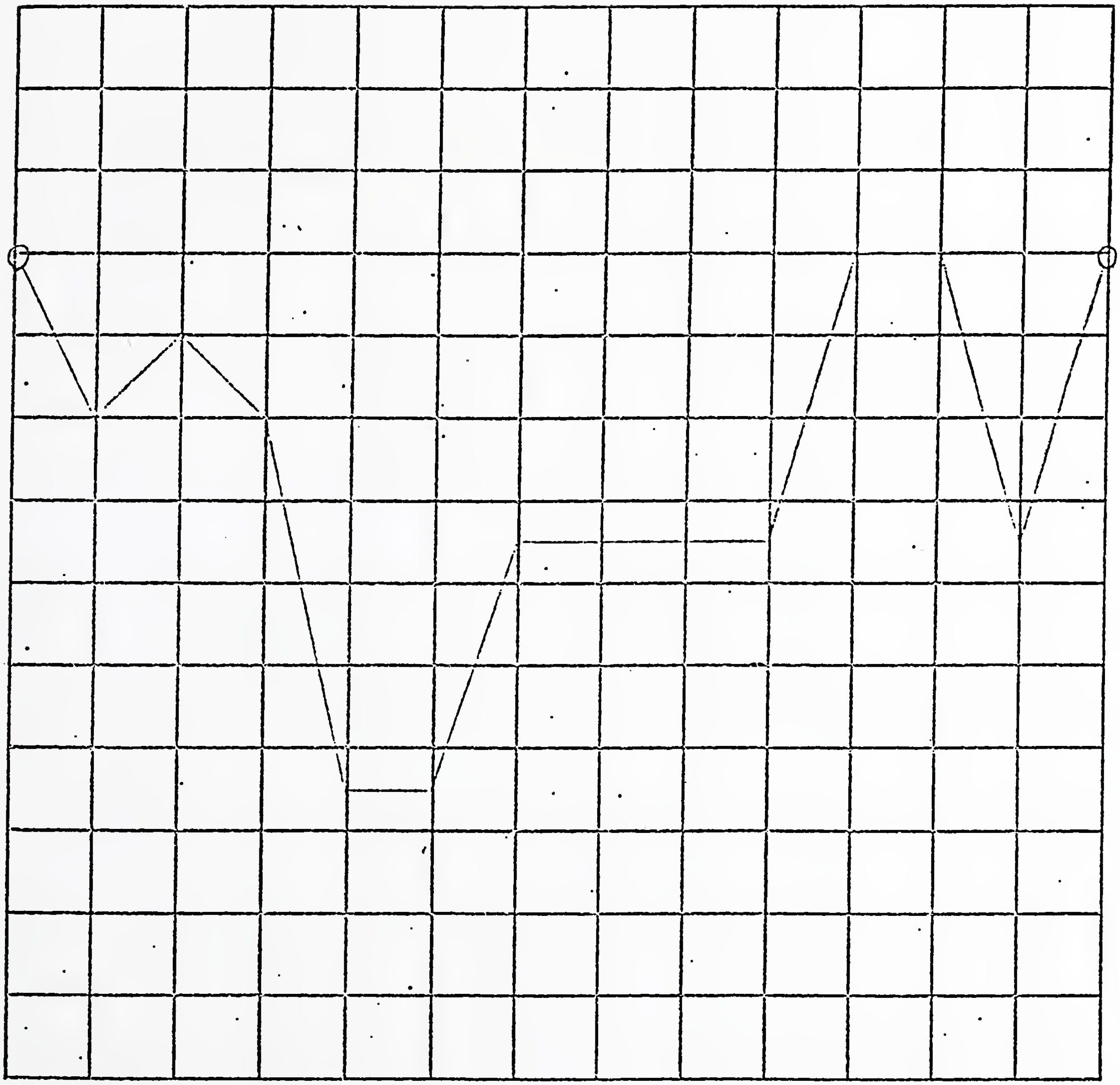
Line Configurations



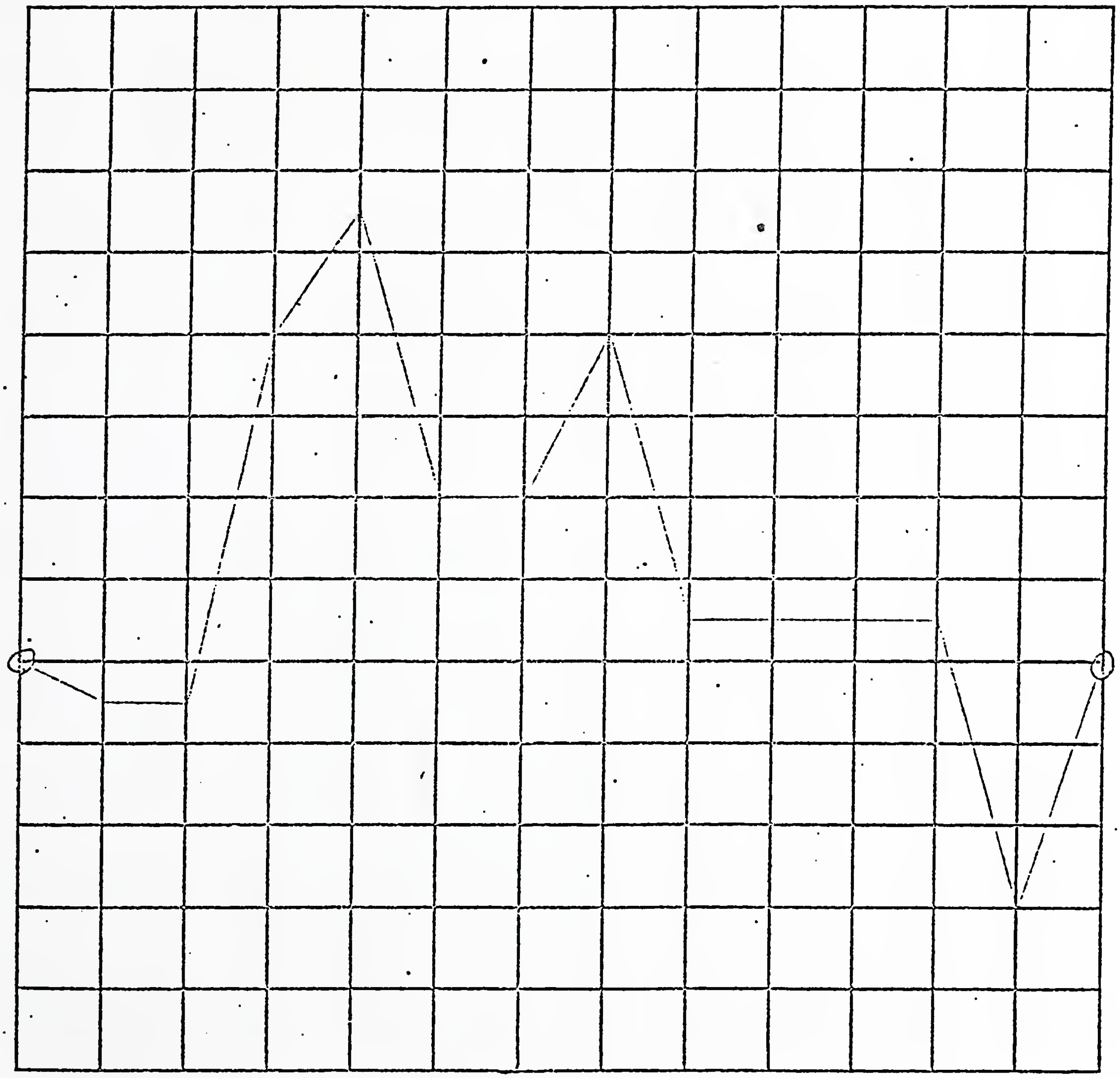
Wide Continuous Line (Grid)



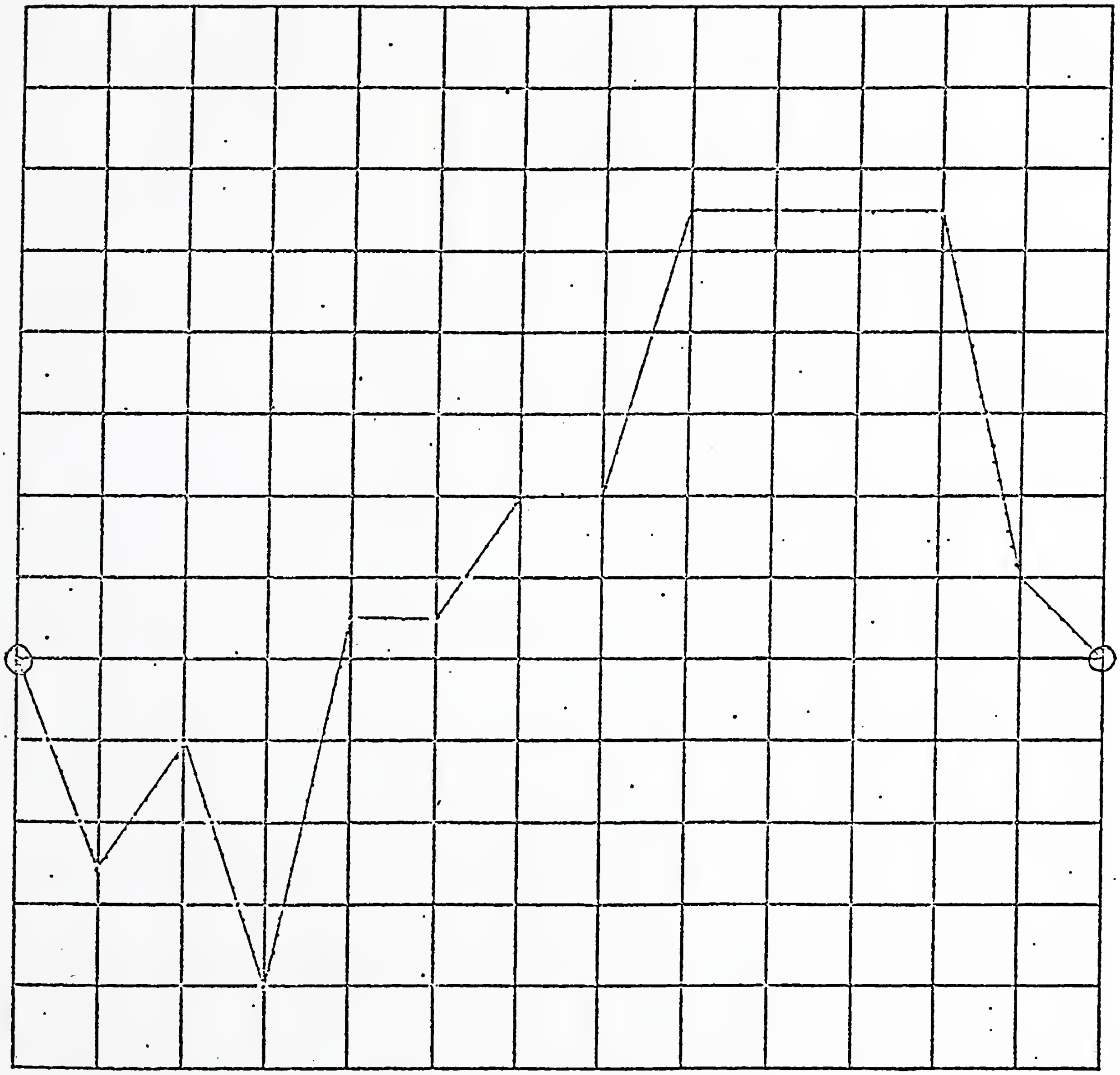
Wide Continuous Line (No Grid)



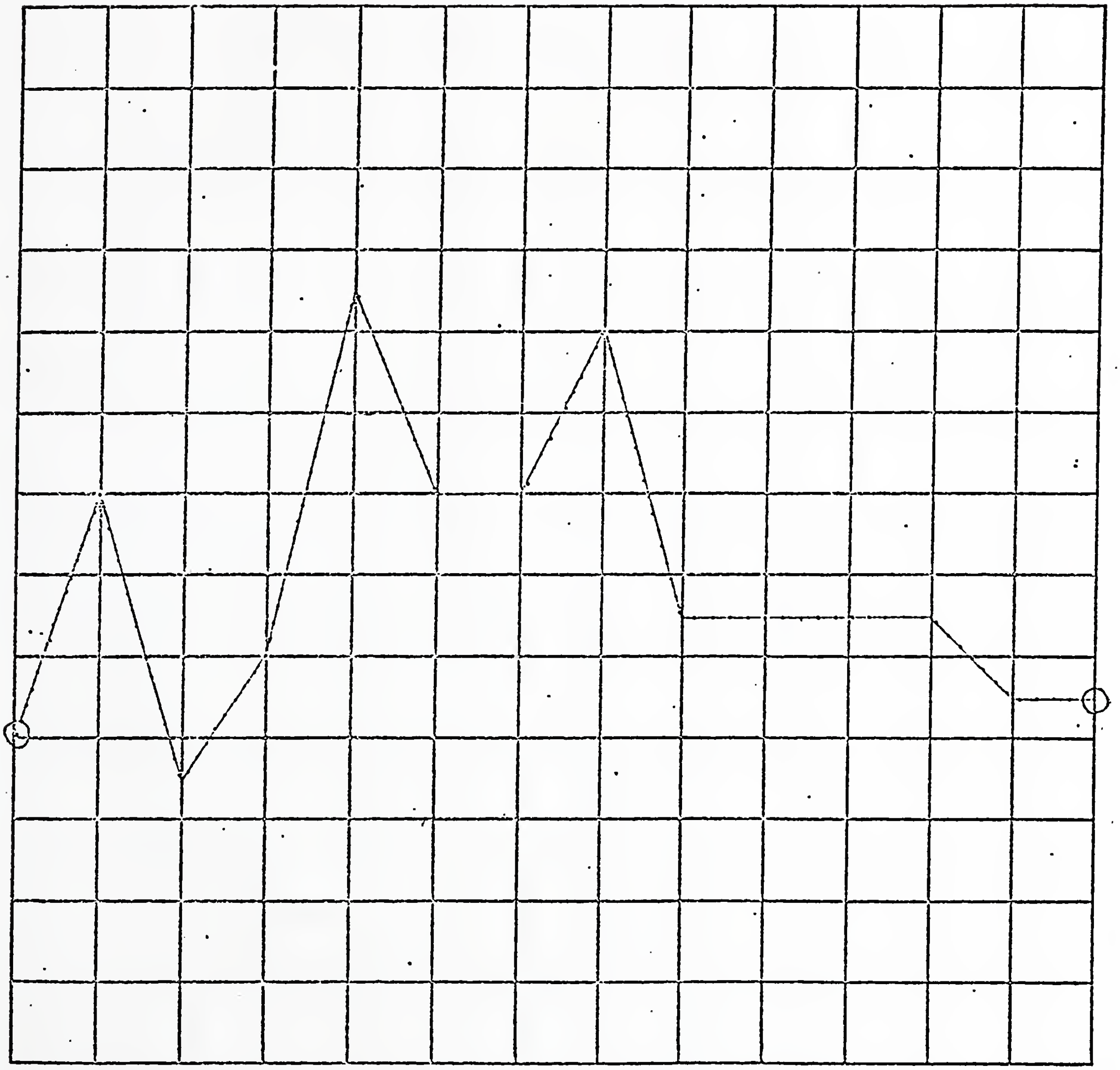
Thin Continuous Line (Grid)



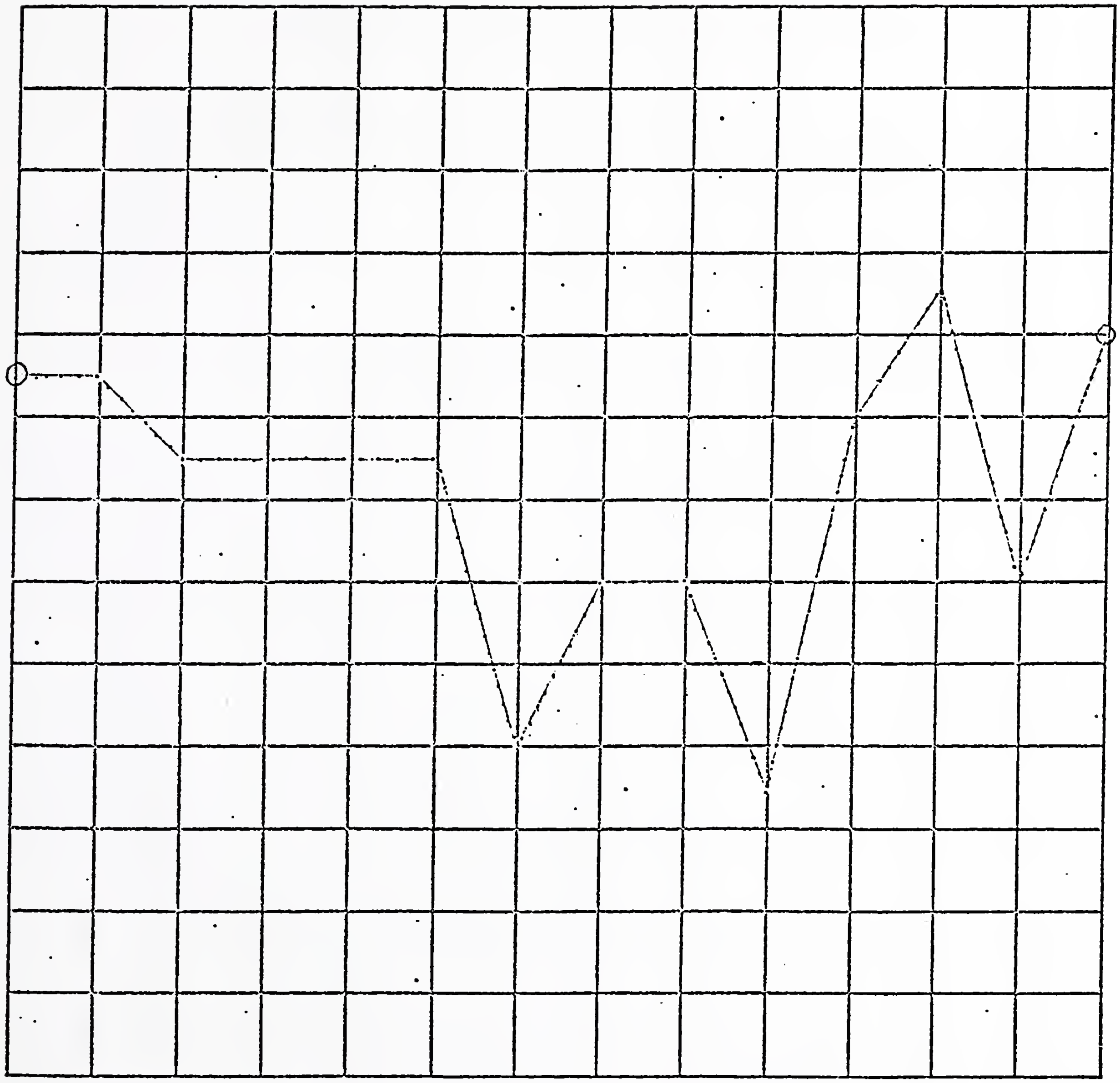
Thin Continuous Line (No Grid)



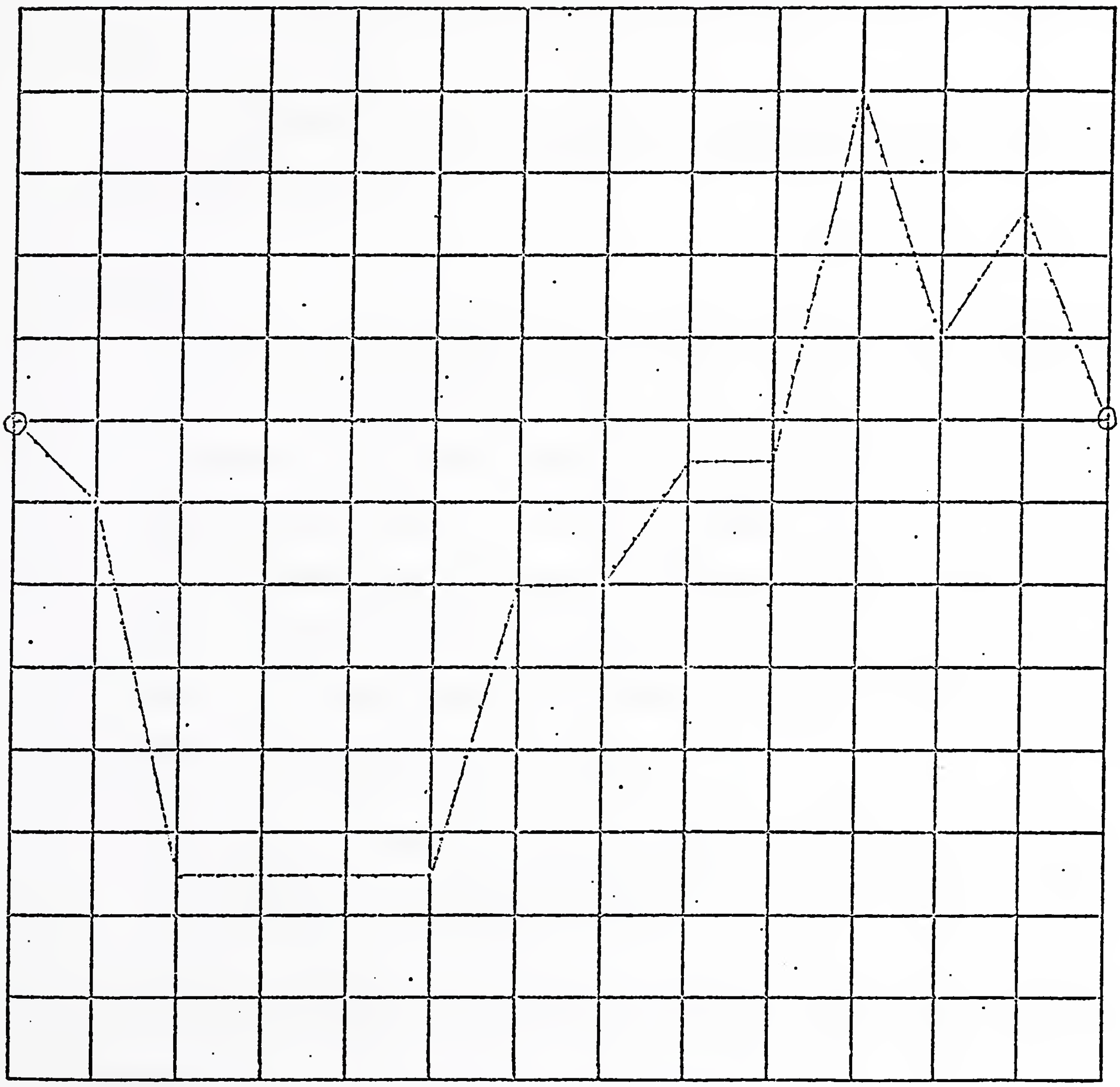
Wide Interrupted Line (Grid)



Wide Interrupted Line (No Grid)



Thin Interrupted Line (Grid)



Thin Interrupted Line (No Grid)

Appendix B

INSTRUCTIONS TO SUBJECTS

Session I

Introduction and Training

Introduce self and say you are from the American Printing House for the Blind.

Then get needed demographic information (grade level, age, experience with raised line maps, etc.).

Then say:

> I'M HERE AT YOUR SCHOOL TO DO A STUDY TO SEE HOW WELL STUDENTS CAN TRACE DIFFERENT KINDS OF RAISED LINES. DURING THE NEXT FEW DAYS, A NUMBER OF THE STUDENTS HERE WILL BE HELPING ME WITH THIS STUDY. THE REASON FOR DOING IT IS TO GET INFORMATION THAT WILL HELP US AT THE PRINTING HOUSE IMPROVE THE MAPS AND GRAPHS WE MAKE. IF YOU WANT TO TAKE PART, (student's name), YOUR TASK FOR THE NEXT 2 DAYS WILL BE TO TRACE A NUMBER OF DIFFERENT RAISED LINES WITH YOUR FINGERTIPS. WOULD YOU LIKE TO DO THIS?
>
> > (Indicate informed consent received from student on record sheet--also demographic info.)

If the student wants to participate, continue; if not, dismiss politely.

Then say:

> BEFORE WE START, I WILL SHOW YOU HOW I WANT TO TRACE A LINE. WE HAVE FOUND A WAY TO TRACE LINES THAT MAKES IT A LITTLE EASIER.
>
> WHENEVER YOU TRACE A LINE, USE YOUR 2 INDEX FINGERTIPS. (Show which two these are.)

YOUR RIGHT FINGERTIP WILL ALWAYS LEAD THE WAY, WHILE YOUR LEFT FINGERTIP WILL TRAIL BEHIND OR FOLLOW. IF YOUR LEADING FINGERTIP LOSES TRACK OF THE LINE, YOU WILL BE ABLE TO FIND YOUR WAY BACK TO THE LINE BECAUSE YOUR LEFT ONE WILL STILL BE ON IT.

(Place student's fingertips on line and move them for him until he gets the idea.) ANY QUESTIONS?

(Have him follow the line on training graph #1, intervening where necessary.)

(Now invert training graph #1 and have student trace it by himself.) I WILL PLACE YOUR FINGERTIP ON THE BEGINNING OF THE LINE. FOLLOW IT TO THE END WITHOUT MY HELP BY USING THE TWO-FINGER METHOD YOU JUST LEARNED. DO IT AS QUICKLY AS YOU CAN BECAUSE I WILL BE TIMING YOU WITH A STOPWATCH.

(If time exceeds 2 minutes, point out problems, invert graph #1, and try again.)

(Now introduce student to training graph #2--grid only. Explain grid design while student tactually explores the graph.) THIS CROSSING OF LINES IS CALLED A GRID. HALF OF THE LINES GO FROM ONE SIDE TO THE OTHER, HALF GO FROM TOP TO BOTTOM. (Direct fingertip along each of these.) (Direct overall scan.) ANY QUESTIONS?

THE NEXT GRAPH I'M GOING TO SHOW YOU HAS A GRID AND A LINE GOING THROUGH THE GRID. USING THE TWO-FINGER METHOD, I WANT YOU TO FOLLOW THE LINE. (Have student feel the line he is to follow.) I'LL PLACE YOUR FINGERTIP AT THE BEGINNING OF THE LINE. TRACE THIS LINE TO THE

END AS QUICKLY AS YOU CAN WHILE STAYING ON THE LINE.

(If student fails to complete the task in 2 minutes, invert the graph and have him try again.)

Line Tracing (Test Phase)

I HAVE FOUR MORE LINES I WANT YOU TO TRACE TODAY. THEY ARE ALL DIFFERENT.

THIS IS THE LINE YOU'LL BE TRACING NEXT. (Have student feel line for 5 seconds.)

I AM PLACING YOUR FINGERTIP AT THE BEGINNING OF THE LINE. WHEN I SAY "GO," FOLLOW THE LINE TO THE END AS QUICKLY AS POSSIBLE WHILE STAYING ON THE LINE. (Time with stopwatch.)

(Repeat above procedure for next three graphs.)

Session II

Line Tracing

TODAY WE ARE GOING TO START BY HAVING YOU TRACE FOUR LINES JUST LIKE YOU DID YESTERDAY. (Have student demonstrate two-finger method on training graph #1 or #3, depending on which grid condition he is in.)

(Repeat procedure used in Session I for each of the four graphs.)

Discrimination

I AM GOING TO ASK YOU TO DO SOMETHING DIFFERENT NOW.

I HAVE PLACED TWO RAISED LINES BEFORE YOU ON THE BOARD. (These are a sample pair--the ones used in training.)

I WANT YOU TO TACTUALLY EXAMINE THEM AND THEN TELL ME WHETHER YOU THINK THEY ARE ALIKE OR DIFFERENT.

YOU WILL DO THE SAME THING FOR 15 MORE PAIRS OF LINES. ANY QUESTIONS?

(Proceed with the 15 pairs.)

Line Ranking

DURING THE TWO SESSIONS OF THIS STUDY, YOU HAVE TRACED FIVE DIFFERENT RAISED LINES. I AM PLACING THEM ON THE TABLE IN FRONT OF YOU NOW. I WANT YOU TO FEEL ALL OF THEM AND THEN PICK OUT THE ONE YOU THINK IS EASIEST TO TRACE. (Subject selects a line.) NOW SHOW ME WHICH OF THE FOUR REMAINING LINES IS EASIEST TO TRACE. (Continue until only one is left.)

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